PHASE TRANSFORMATIONS DURING THERMAL TREATMENT OF ALLOY VT18

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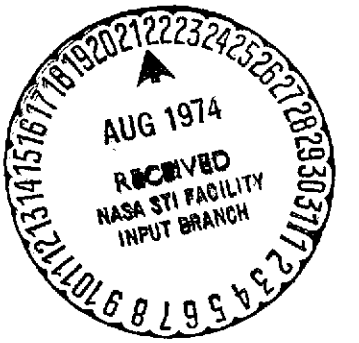

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16. Abstract

The VT18 alloy was investigated during heat treatment, and it was shown that at temperatures below 930°, the α_2-phase and some of the β-phase are present, apart from the α-matrix. During aging, the changes are determined by the formation of the ordered α_2-phase. After longer exposure, the β-phase decomposes. The instability of VT18, at working temperatures, is due to the ordering of the α-solid solution and decomposition of the β-phase.

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In this work, research was done into the VT18 titanium alloy, which has a combination of strength and creep resistance between 550 and 600°, and is the most heat-resisting domestic titanium alloy. However, this alloy has reduced stability of properties, manifest in the change of strength and plasticity during prolonged exposure in working temperatures. The constant of elastic strain and contraction may vary by 25-50%. /74*

The present research, devoted to studying phase and structural variations when hardening and tempering the VT18 alloy, was conducted on rods compressed at 900-1000°. The rods were cut into bars and thermally processed. Specimens were cut from the bars for investigating the microstructure, and for x-ray and dilatometric analysis. X-ray analysis was carried out on a URS-50 IM diffractometer and in x-ray diffraction and x-ray optical spectrometry chambers in copper and nickel radiations. Dilatograms were obtained on a UVD dilatometer. Electron microscopic research was carried out on a UEMV-100 microscope by the replica method.

Measurement of the width of the x-ray interference line (114) of the α-solid solution and microhardness, depending on the hardening temperature (in the temperature region of 500-1100°) showed the presence of four temperature regions of the phase state of the alloy, characterized by the simultaneous increase or reduction of the indicated parameters (Fig. 1). Dilatometric research during continuous heating of quenched specimens shows that volume changes occur during the same temperatures (Fig. 2, a).

*Numbers in the margin indicate pagination in the foreign text.

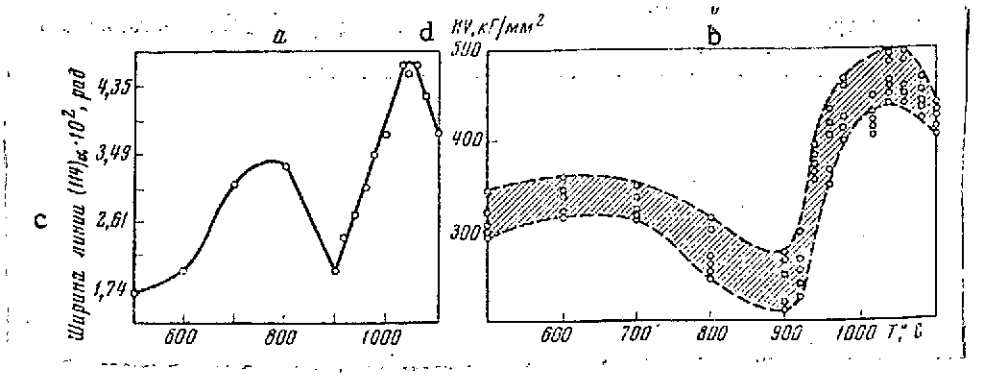

Fig. 1. Change in the width of the line (114) of the α-phase (a) and microhardness (b), depending on the hardening temperature.

Key: c. Width of line (114) $\alpha \cdot 10^2$, rad
d. HV, kgf/mm^2

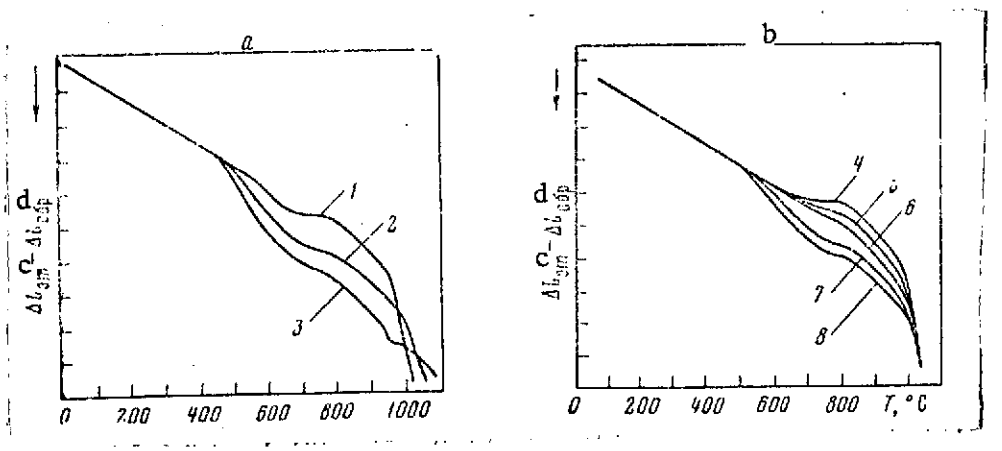

Fig. 2. Dilatograms obtained during continuous heating of specimens, quenched from 900, 1000 and 1100° (a) and previously cooled in air from 900° and aged at 500-800° for 100 hours (b).

T, °C: 1 - 900; 2 - 1000; 3 - 1100; 4 - 500; 5 - 550; 6 - 600; 7 - 700; 8 - 800.

Key: c. std
d. sam

Research into the phase composition showed that, in all cases, during hardening there are three phases -- α, α_2 and β. Lines of the α_2-phase are only distinct at low hardening temperatures, and at a hardening temperature above 700°, one can judge whether the α_2-phase is present according to the presence of diffuse

rings on x-ray photographs. There are no lines of the β-phase on x-ray photographs taken in the x-ray diffraction chamber, and they only show during increased conditions in the diffractometer. The presence of the β-phase is also confirmed by studying the microstructure with an electron microscope (Fig. 3, a-c).

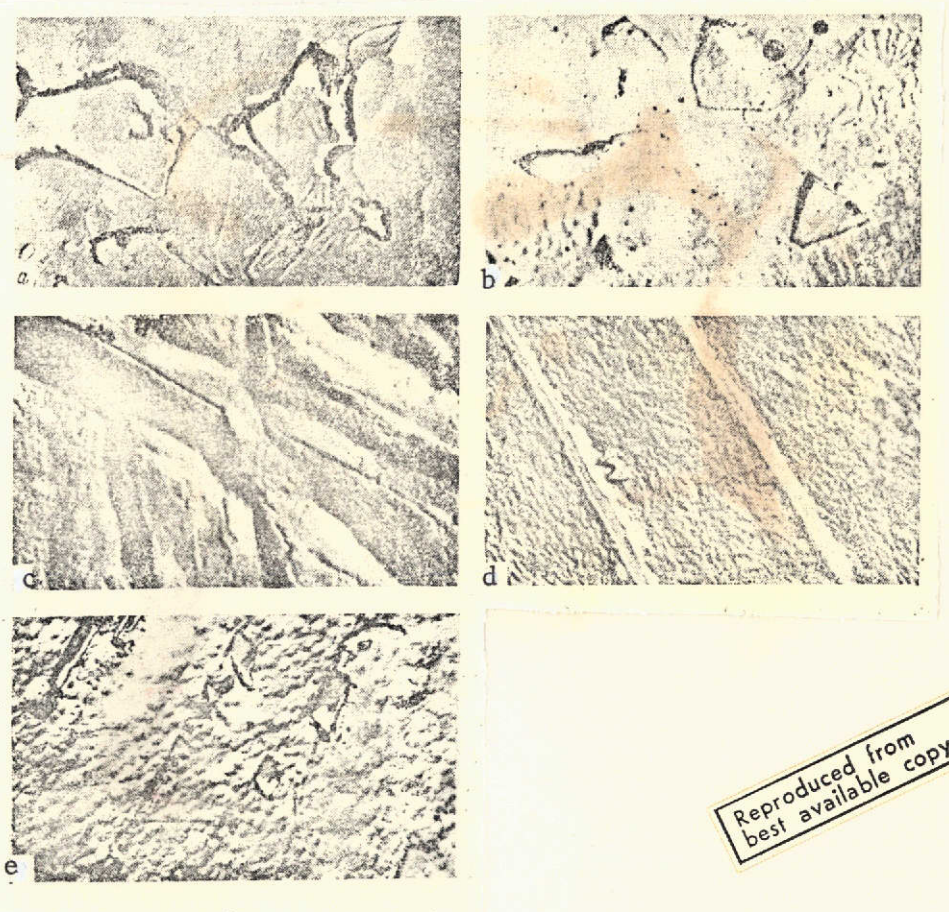

Fig. 3. Structure of specimens quenched from 600 (a), 900 (b), and 1000° (c), cooled in air from 900° (d), and aged at 600° for 500 hours (e).

The information obtained coincides well with a state diagram compiled for alloys of the TiAl system [1]. A change of properties during the temperature hardening interval of 500-800° can be linked with ordering processes, causing the formation of the α_2-phase. /75

The absence of change of volume and the fall in the width of the x-ray line and hardness during temperatures of 800-930°, apparently, is linked with annealing processes in the single-phase α-region. The increase of hardness and width of line at temperatures of 930-1060° with a transition to the region (α + β), and the reduction of these parameters is linked with a transition to the β-region. Measurement of particle size of the α_2-phase, according to the width of x-ray interference lines, showed that during quenching from 1000-1100°, their size is only approximately 20 Å. /76
The measured parameters of the lattice of the α-phase are close to parameters established in works [1, 2] and are: a = 5.789 Å, c = 4.649 Å.

During the work, no other ordered phases apart from the α_2-phase (Ti_3Al) were detected. The presence of wide lines at narrow angles θ (diffuse rings), in our opinion, are linked not with the formation of the Ti_3Al phase, with parameters of a = 11.52 Å and c = 4.68 Å, as stated in work [3], but with the presence of the close order during the formation of the α_2 phase. The presence of diffuse rings on x-ray photographs shows that quenching does not completely eliminate the ordering process. Apparently, this is linked with the fact that the ordering temperature for this alloy is quite high (~780-800°) and is in the region for the relatively high diffused mobility of atoms. As opposed to information in work [1] on alloys of the Ti-Al system, when a VT18 alloy is quenched from temperatures of 930-1100°, α'-martensite is formed. This is obvious by its microstructure and the sharp increase of hardness and line width on x-ray photographs (see Figs. 1, 3, c).

The basic results showing the uniformities for transformations during tempering of the VT18 alloy, were obtained by the dilatometric method. Figure 2, c shows curves for the change of elongation of samples during continuous heating after cooling in

air from 900°, and aging for 100 hours at 500-800°. Information shown in this figure indicates that the course of curves showing changes of elongation is different for samples aged at 500-600°, on one hand, and 700-800° on the other. This difference in the course of curves is determined by the fact that the phase composition of specimens is different: at 500-600°, a considerable quantity of the α_2-phase is formed; at 700°, its quantity is very small; and at 800°, there is no α_2-phase. Therefore, whereas for specimens aged at 500-600°, the change in the volume will only be linked with the disordering process, for specimens aged at 700-800°, this change will be linked, at first, with the ordering process, occurring during heating to relatively low temperatures, and with an increase of temperature -- with disordering processes.

Dilatometric curves, obtained during isothermal research of specimens quenched from 900-1100°, show that in the region of temperatures examined (400-600°) there is a reduction of volume during the early stages of aging, linked with the formation of the α_2-phase. The time when the ordering process finishes depends on the hardening temperature, and the higher the hardening temperature, the faster the ordering process occurs (Fig. 4). Hence, after quenching from temperatures above 930°, martensite is formed. Apparently, the ordering process occurs easily in the distorted lattice of martensite, with an identical crystal lattice to the α-phase, than in the little-distorted α-phase itself. /77

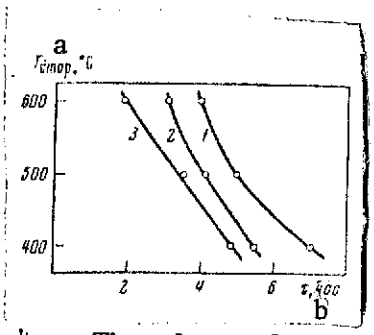

Fig. 4. The dependence on the time when the ordering process finishes on the hardening temperature and aging. T_{hard}, °C: 1 - 900; 2 - 980; 3 - 1100.

Key: a. Aging
b. Hours

The β-phase, observed in all research conditions, and the presence of which in the structure is linked, probably, with the

irregularity with respect to molybdenum and vanadium, did not remain unchanged during aging. Research into the microstructure under an electron microscope showed that the β-phase decomposes; this is particularly noticeable after aging for 500 hours at 600° (Fig. 3, e). Later stages of this long aging are accompanied by an increase in plasticity, which is linked mainly with a structure change: during decomposition, plates of the β-phase are transformed into globules, and, as is known, a structure with globular inclusions is more plastic than with laminar ones.

Figure 5 shows curves illustrating the property changes of the VT 18 alloy after aging for 100 hours at 550-750°. Figure 5 shows that the increase in the aging temperature causes an increase of plasticity, and during aging, the elongation in the α-region is approximately 6% greater than in the region $(\alpha + \alpha_2)$. Therefore, it is possible that preliminary processing in the temperature region close to the transition temperature of $\alpha \rightarrow (\alpha + \beta)$, with subsequent short-term aging in the working temperature ranges increases the stability of properties of the alloy with sufficient plasticity.

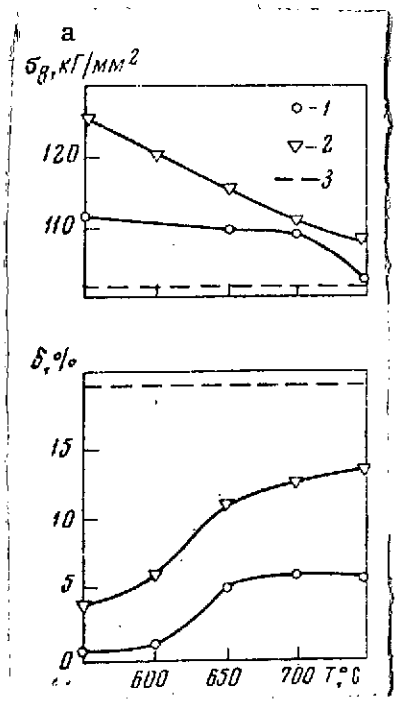

Fig. 5. The change of mechanical properties of specimens and bars of VT18 alloy depending on the aging temperature aging time of 100 hours. 1 - specimen; 2 - bars; 3 - initial state.

Key: a. kgf/mm^2

Conclusions

1. It was shown that during quenching from temperatures below 930°, apart from an α-matrix, there is an ordered α_2-phase and a certain amount of β-phase in a VT18 alloy. When quenching from temperatures above 930°, the structure consists of martensite of the α'-, α_2- and β-phases.

2. It was established that when the VT18 alloy is aged, during the first stages of aging the change of properties is determined by the formation of an ordered α_2-phase. It was shown that during longer exposures, there is a decomposition of the β-phase.

3. Apparently, the instability of properties of the VT18 alloy during working temperatures is determined by processes linked with the ordering of the α-solid solution and decomposition of the β-phase.

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